Non Standard SUSY searches at LEP

J. Fay

NON "STANDARD" SUSY SEARCHES AT LEP

JEAN FAY
Institut de Physique Nucléaire de Lyon,
IN2P3/CNRS and Université Claude Bernard

Data collected by the LEP experiments in e^+e^- collisions are analysed under the assumption of different extensions to the Minimal SuperSymmetric Model:
- Searches performed assuming that R-parity is not conserved.
- Searches in the framework of GMSB model: the gravitino is the LSP. The NLSP can be either the neutralino or a slepton. Depending on the decay length of the SUSY particles, different topologies are expected.
At center-of-mass energies between 189 GeV and 202 GeV no signal is found. Limits on the production cross sections and on the masses of the supersymmetric particles are derived.

1 Introduction

This presentation is divided in two sections:

- R-parity violation
- Gauge Mediated Supersymmetry Breaking

The results come from the 4 LEP experiments: ALEPH, DELPHI, L3 and OPAL. They have been obtained from data taken at 192 GeV $\leq \sqrt{s} \leq$ 202 GeV.

2 R-parity violation

2.1 Introduction to $\not{R}_P$

The R-parity is a new multiplicative quantum number defined as $R_P = (-1)^{3B+L+2S}$. When R_P is conserved, the lightest supersymmetric particle (LSP) is stable and the SUSY particles are pair produced. If R_P is violated, the SUSY particles may decay to standard ones and the LSP is not stable. Searches for R-parity violating decays of pair produced gauginos and s-fermions have been actively performed. Recently, the four experiments have also studied the production

of a single sparticle.
The most general superpotential includes 3 trilinear terms:

$$W_R = \lambda_{ijk} L_i L_j \overline{E}_k + \lambda'_{ijk} L_i Q_j \overline{D}_k + \lambda''_{ijk} \overline{U}_i \overline{D}_j \overline{D}_k$$

where λ_{ijk}, λ'_{ijk} and λ''_{ijk} are the Yukawa couplings, i, j, k the generation indices; λ_{ijk}, λ'_{ijk} couplings violate the leptonic quantum number while λ''_{ijk} couplings violate the baryonic one.

In all the searches, the LSP lifetime has been assumed to be negligible.

2.2 Gaugino pair production

Table 1 presents the direct decay of the gauginos. For the indirect decays, the final states will be the same with 2Z* decay products ($\tilde{\chi}^0_j \to \tilde{\chi}^0_1 Z^*$) or 2W* decay products ($\tilde{\chi}^\pm \to \tilde{\chi}^0_1 W^*$).

Table 1: Direct gaugino decays.

	λ	λ'	λ''
$\tilde{\chi}^0$	$\nu\ell\ell$	ℓqq or νqq	qqq
$\tilde{\chi}^\pm$	$\ell\ell\ell$ or $\ell\nu\nu$	ℓqq or νqq	qqq

No significant excess has been observed and cross section upper limits are set, areas in MSSM parameter space are excluded and lower limits on sparticle masses (Fig. 1-a)[1] are obtained. From a scan over M_2, μ, tanβ, m_0, one can derive limits on gaugino masses (Fig. 1-b).[2]

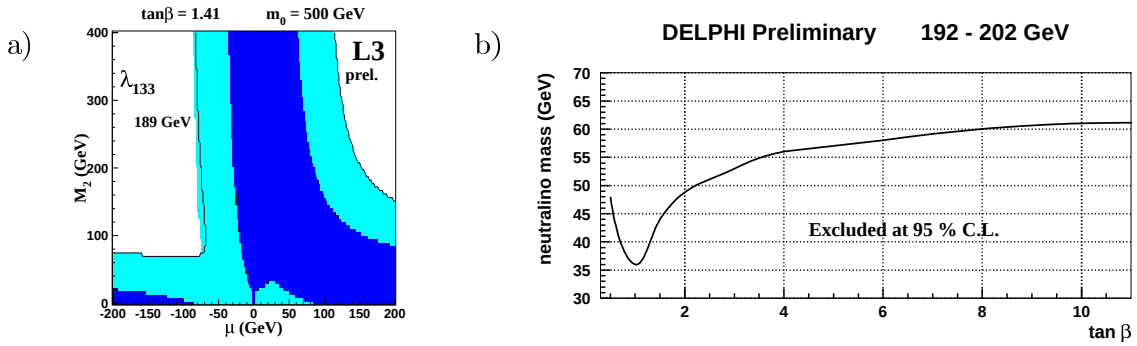

Figure 1: (a)λ: L3 exclusion region for λ_{133}, (b)λ': DELPHI excluded lightest neutralino mass as a function of tan β.

The current mass limits range from 36 to 37.5 GeV for $\tilde{\chi}^0_1$ and almost reach kinematic limit for $\tilde{\chi}^\pm_1$.

2.3 Sfermion pair production

The direct decay modes of sfermions are summarized in Table 2. A sfermion can also decay indirectly to a fermion of the same flavour and the lightest neutralino ($\tilde{\nu} \to \nu\tilde{\chi}^0_1$, $\tilde{\ell} \to \ell\tilde{\chi}^0_1$, $\tilde{q} \to q\tilde{\chi}^0_1$).
No significant excess has been observed. Cross section upper limits as a function of $m_{\tilde{f}}$ are set and areas in $m_{\tilde{\chi}^0_1}$ versus $m_{\tilde{f}}$ plane are excluded (Fig. 2).[3]

Table 2: Direct sfermion decays.

	λ	λ'	λ''
$\tilde{\nu}$	$\ell\ell$	qq	-
$\tilde{\ell}$	$\nu\ell$	qq	-
$\tilde{q}$	-	νq or ℓq	qq

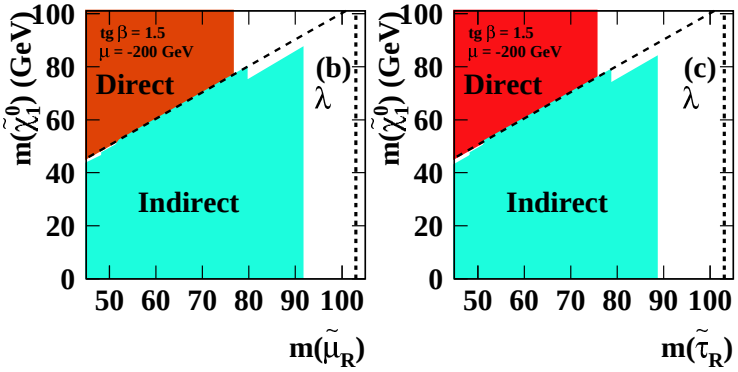

Figure 2: λ: OPAL preliminary exclusion regions for (b) $\tilde{\mu}^+\tilde{\mu}^-$ and (c) $\tilde{\tau}^+\tilde{\tau}^-$.

2.4 Single sparticle production

ALEPH [4] has searched for single sneutrino production through the process $e\gamma \to \tilde{\nu}\ell$. Only λ_{1j2} ($\tilde{\nu} \to e\mu$) is different from 0, thus the sneutrino is assumed to decay via the same coupling and the final state is (e)e$\mu^+\mu^-$. Data are in good agreement with the background expected from the Standard Model. Areas in $m_{\tilde{\nu}}$ versus λ_{1j2} plane are excluded. From a search for a single gaugino production ($e^+e^- \to \tilde{\nu} \to \nu\tilde{\chi}^0$ and $\ell^{\mp}\tilde{\chi}^{\pm}$), DELPHI [2] can exclude regions in $m_{\tilde{\nu}}$ versus λ_{121} plane.

3 Gauge Mediated Susy Breaking

In gravity mediated Susy Breaking (SUGRA), the supersymmetry breaking mechanism is supposed to occur at very high energy and the gravitino is too heavy to be produced at LEP.

On the other hand, in Gauge Mediated Susy Breaking (GMSB) models, the supersymmetry breaking takes place at much lower energy scale $\sqrt{F}$ and the gravitino $\tilde{G}$ with mass:

$$m_{\tilde{G}} = \frac{F}{\sqrt{3}\, M_P} \simeq 2.5 \text{ eV} \left(\frac{\sqrt{F}}{100\text{TeV}}\right)^2$$

becomes the Lightest Susy Particle (LSP).

The Next to Lightest Susy Particle (NLSP) can be either a right handed scalar lepton $\tilde{\ell}_R^{\pm}$ or the neutralino $\tilde{\chi}_1^0$. The NLSP decay length:

$$D.L. \simeq (17\mu\text{m})\sqrt{\frac{E_{\text{NLSP}}^2}{m_{\text{NLSP}}^2} - 1}\left(\frac{m_{\tilde{G}}}{1 \text{ eV}}\right)^2 \left(\frac{m_{\text{NLSP}}}{100 \text{ GeV}}\right)^{-5}$$

can be non negligible and very different topologies are obtained, depending on the NLSP type and decay length.

3.1 NLSP: right handed scalar lepton $\tilde{\ell}^{\pm}_{R}$

The $\tilde{\ell}$ decays to $\tilde{G}\ell^{\pm}$, leading to the process $e^+e^- \to \tilde{\ell}^+\tilde{\ell}^- \to \tilde{G}\tilde{G}\ \ell^+\ell^-$. Depending on the decay length of the $\tilde{\ell}^{\pm}_{R}$, the expected topology will be a pair of acoplanar leptons (D.L. $\leq$ 1cm), kinks or large impact parameter (D.L. $\leq$ 1m) and heavy stable charged particles (higher D.L.). The indirect searches include $\tilde{\chi}^0_1 \to \tilde{\ell}\ell$ ($e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_1 \to \tilde{G}\tilde{G}\ell^+\ell^-\ell'^+\ell'^-$), $\tilde{\chi}^{\pm} \to \tilde{\ell}\nu_\ell$ ($e^+e^- \to \tilde{\chi}^+\tilde{\chi}^- \to \tilde{G}\tilde{G}\nu_\ell\nu_{\ell'}\ell^+\ell'^-$) and $\tilde{\ell} \to \ell\tilde{\tau}\tau$ ($e^+e^- \to \tilde{\ell}^+\tilde{\ell}^- \to \tilde{G}\tilde{G}\tau^+\tau^-\tau^+\tau^-\ell^+\ell^-$).
No excess has been observed and regions in the plane $m_{\tilde{\ell}}$ versus $m_{\tilde{G}}$ or $\tilde{\ell}$ lifetime are excluded.

3.2 NLSP: the lightest neutralino $\tilde{\chi}^0_1$

The NLSP $\tilde{\chi}^0_1$ decays to $\tilde{G}\gamma$ and the following processes have been considered: $e^+e^- \to \tilde{G}\tilde{\chi}^0_1 \to \tilde{G}\tilde{G}\gamma$ and $e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_1 \to \tilde{G}\tilde{G}\gamma\gamma$ in direct searches. The indirect processes: $\tilde{\chi}^{\pm} \to \tilde{\chi}^0_1 W^*$ ($e^+e^- \to \tilde{\chi}^+\tilde{\chi}^- \to \tilde{G}\tilde{G}\gamma\gamma$ + 2W decay products), $\tilde{\ell} \to \ell\tilde{\chi}^0_1$ ($e^+e^- \to \tilde{\ell}^+\tilde{\ell}^- \to \tilde{G}\tilde{G}\gamma\gamma\ell^+\ell^-$) and $\tilde{\chi}^0_2 \to \tilde{\chi}^0_1 Z^*$ ($e^+e^- \to \tilde{\chi}^0_2\tilde{\chi}^0_1 \to \tilde{G}\tilde{G}\gamma\gamma$ + Z decay products) have also been searched for. Here again, depending on the decay length of the neutralino, the event topology will be different: acoplanar photon pair if D.L. $\leq$ 1cm, non pointing photon when D.L. $\leq$ 1m and heavy standard chargino and slepton searches for higher D.L.

Figure 3 displays the combination made by the LEP SUSY working group of all the 1 γ and acoplanar 2 γ results obtained by the 4 experiments.

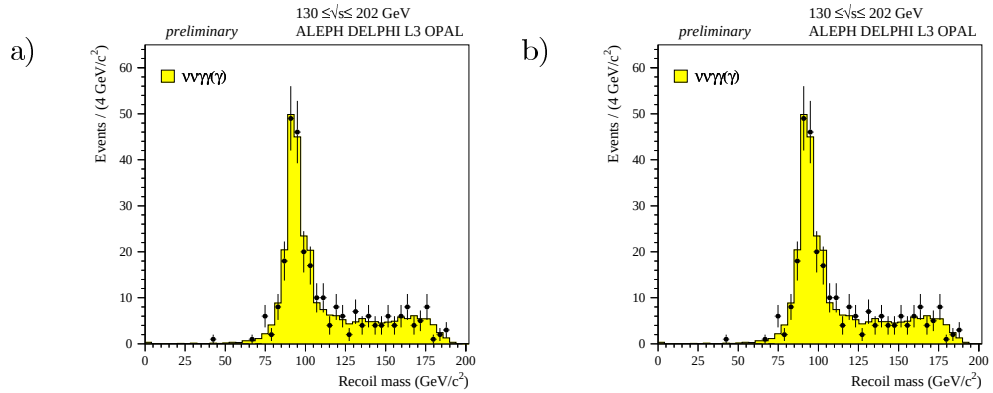

Figure 3: Recoil mass spectrum obtained by the 4 LEP collaborations in 1 γ (a) and acoplanar 2 γ (b) events, compared to KORALZ predictions (from LSWG).

In both cases, no anomaly is found and limits are derived.

For non-zero lifetime of the neutralino, only 1 photon with a large impact parameter is expected from the process $e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_1 \to \tilde{G}\tilde{G}\gamma\gamma$. No excess has been found and limits are set.

4 Conclusions

Many searches for events predicted by SUSY, either with R-parity violation, or in the GMSB framework have been performed by the 4 LEP experiments. No significant excess has been found and new limits have been set.

References

1. L3 collaboration, L3 Note 2585.
2. DELPHI collaboration, DELPHI 2000-084 CONF 383.
3. OPAL collaboration, OPAL physics Note PN435.
4. ALEPH collaboration, ALEPH 2000-027 CONF 2000-022.